TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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AERODYNAMIC TESTS OF A LOW ASPECT RATIO TAPERED WING WITH VARIOUS FLAPS, FOR USE ON TAILLESS AIRPLANES

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SUMMARY

Wind-tunnel tests were made of a model wing having an aspect ratio of 3 and a tapered plan form with a straight trailing edge. The model had the Clark Y airfoil section throughout its entire span and had no washout, depending on a trailing-edge flap for longitudinal balance and control. The flap had a constant chord and was divided into four equal portions along the span. The tests were made with the entire flap deflected to obtain longitudinal control and balance, and also with the inner portions deflected alone, and with the outer portions deflected alone. It was found that the simple wing with no washout or change of basic section along the span has aerodynamic characteristics well suited for use on tailless airplanes. A higher lift coefficient was obtained with the full-span flap deflected as a unit to give longitudinal balance than was obtained with either the inner or the outer portions of the flap deflected.

INTRODUCTION

In the search for an increase of the general performance and the speed range of airplanes, the all-wing type of airplane appears promising. In the ideal airplane, all the usual extraneous parts that produce drag are either entirely lacking or are enclosed within the wing during flight. One step in this direction is the elimination of the tail surfaces and the structure supporting them. This procedure has an additional advantage in military use by removing obstacles in the fields of view and of gunfire.

Work on tailless airplanes has been carried on since the latter part of the nineteenth century (references 1 to 6, inclusive). One of the first tailless airplanes to fly successfully was the Dunne, a pusher biplane with extreme sweepback, which was flown in 1910. The Dunne airplane had good longitudinal stability but insufficient control to overcome this stability and change the angle of attack more than a few degrees. This inability to change attitude was no great handicap, as the power loading of airplanes of that time gave them but a small speed range.

During the past few years the most outstanding work in this field has been the development of the Hill "Pterodactyls" in England and of the Lippisch designs in Germany. The performance of these airplanes has been remarkably good. They, as well as the Dunne, have high aspect ratio wings and have obtained balance with the center of gravity sufficiently far ahead for longitudinal stability by means of sweepback combined with washout. The Dunne airplane had the same airfoil section and chord along the entire span, but the Hill and Lippisch designs have tapered plan forms, and obtain an effective washout by a gradual reduction of camber toward the tips of the wings. The Lippisch designs have thick highly cambered Joukowsky-type sections at the center, with thin inverted or negative camber sections at the tips to give longitudinal stability.

The tests described in this report are the first in an investigation by the N.A.C.A. of the aerodynamic characteristics of possible tailless arrangements. The investigation will be extended to include whatever range is thought most desirable and may include, among other things, variations in aspect ratio, taper, sweepback, washout, airfoil section, dihedral, and also control flaps or other control devices of different forms and proportions.

The present tests were made with a model wing having a low aspect ratio with a large amount of taper and a straight trailing edge, an arrangement which was considered advantageous in obtaining a relatively large area, and therefore low landing speed, with small over-all dimensions. The large chord should also be advantageous in damping longitudinal oscillations. The model was provided with a constant-chord flap, which extended along the entire span and was divided into four sections. These sections were used in different combinations to produce pitching moments for longitudinal control and balance. A full-span split-type upper-surface flap was also tested. The wing was constructed with a constant airfoil section (Clark Y) and with no washout but, because of the tapered plan form, turning up the flaps gave the effect of washout and of reduced camber at the tips.

APPARATUS

Wind tunnel.- The tests were made in the N.A.C.A. 7 by 10 foot wind tunnel, which is described in detail in reference 7. They were made at a dynamic pressure of 16.37 pounds per square foot, which corresponds to an air speed of 80 miles per hour under standard atmospheric conditions at sea level. The Reynolds Number for this speed is 933,000, based on the mean aerodynamic chord of the model, which is defined as the chord at the centroid of the semiwing (reference 8). No corrections were made for tunnel-wall interference.

Model.- The model (fig. 1), which was constructed of laminated mahogany, had a span of 42.43 inches and an aspect ratio of 3. It had a 3:1 taper, the chord at the center being 21.21 inches and that at the tip being 7.07 inches. The Clark Y section was used over the entire span as the basic section with the flap neutral. The upper extremities of the maximum ordinates of the upper surface were all located in a plane parallel to the chord line of the root section, giving the wing a certain effective dihedral angle. The flap was hinged parallel to the trailing edge. Its chord was one half the wing chord at the tip and one sixth the wing chord at the center, and its area was one fourth the total wing area. The gap between the flap and the main portion of the wing was sealed with Plasticine for each test, and the V cut between the flap sections at the center, which was necessary to permit their upward deflection, was covered with adhesive paper.

TESTS

The first tests were made to find the lift, drag, and center of pressure with the entire flap deflected upward various amounts. The results are given in figure 2. The center of pressure is given in terms of the mean aerodynamic chord as previously defined, which has a value in this case of 15.32 inches. A stable center-of-pressure movement was obtained with the entire flap set up 7° or more.

In the next tests a flap setting of 7° was considered a neutral position, and with the outer portions of the flap set at the 7° value the tests were run with the inner portions set at various angles. This represented a condition in which the outer portions of the flap were used as ailerons and the inner portions as elevators. The results are given in figure 3.

In the third set of tests, the inner portions of the flap were set at the 7° angle and the outer portions at various angles, representing the condition in which the inner portions were a fixed part of the wing and the outer portions were deflected together for elevators and differentially for ailerons. The results of those tests are given in figure 4.

In addition to the foregoing tests with the conventional-type flap, tests were made with the flap portion of the wing set neutral to conform to the basic Clark Y section and with a metal plate deflected upward from the upper surface and forming a split flap, as shown by the inset in figure 1. It was thought that this arrangement might give trim at the high angles of attack without so great a sacrifice in the maximum lift coefficient as that obtained with the conventional-type flap. The split flap proved unsatisfactory, however, in that it became ineffective as the angle of attack was increased, and did not give control at the high angles. The results of these tests are given in figure 5.

DISCUSSION

The maximum lift coefficient that can be obtained in flight with any of these flap arrangements depends on the flap deflection required for trim at the high angles of attack, which in turn depends on the location of the center of gravity of the airplane. An analysis of the present test data indicates that the rearmost position of the center of gravity that can be used without entailing longitudinal instability at the angles of attack near zero lift is 26 percent of the mean aerodynamic chord. In figure 6 are plotted the lift and drag characteristics of the model with the flap deflected the required amounts to give trim at the various angles of attack with the center of gravity assumed at 26 percent of the mean aerodynamic chord. The highest value of $C_{L_{max}}$, 1.07, was obtained with the entire flap deflected as a unit. With either the inner or the outer portions of the flap deflected alone for longitudinal balance, the value of the maximum lift coefficient obtained was 0.99.

The value of $C_{L_{max}}$ obtained in the present tests with a full-span flap and no washout or change of basic section along the span is slightly higher than other values for wings suitable for tailless airplanes that have come to the attention of the authors.

With a flap over the entire span, it seems likely that a smaller chord than the one used in the present tests would give sufficient pitching moment with less loss of lift. In addition, a somewhat lower minimum drag coefficient would obviously be obtained by the use of a basic airfoil having its trailing edge swept up in a smooth manner to give a slightly stable movement of the center of pressure, although even with the present flap, the drag for the high-speed condition is less than that of the plain wing at the same lift coefficient.

CONCLUSIONS

1. A simple low aspect ratio wing having the same airfoil section throughout the span and having zero washout has aerodynamic characteristics suitable for a tailless airplane if provided with a trailing-edge flap.

2. A full-span flap on a wing of the form tested gives longitudinal balance at higher lift coefficients than flaps covering only the outer or the inner half of the span.

3. Further tests seem warranted with the present plan form in which improved flaps or devices such as auxiliary airfoils along the leading edge are used to obtain higher values of the lift coefficient.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., May 23, 1933.

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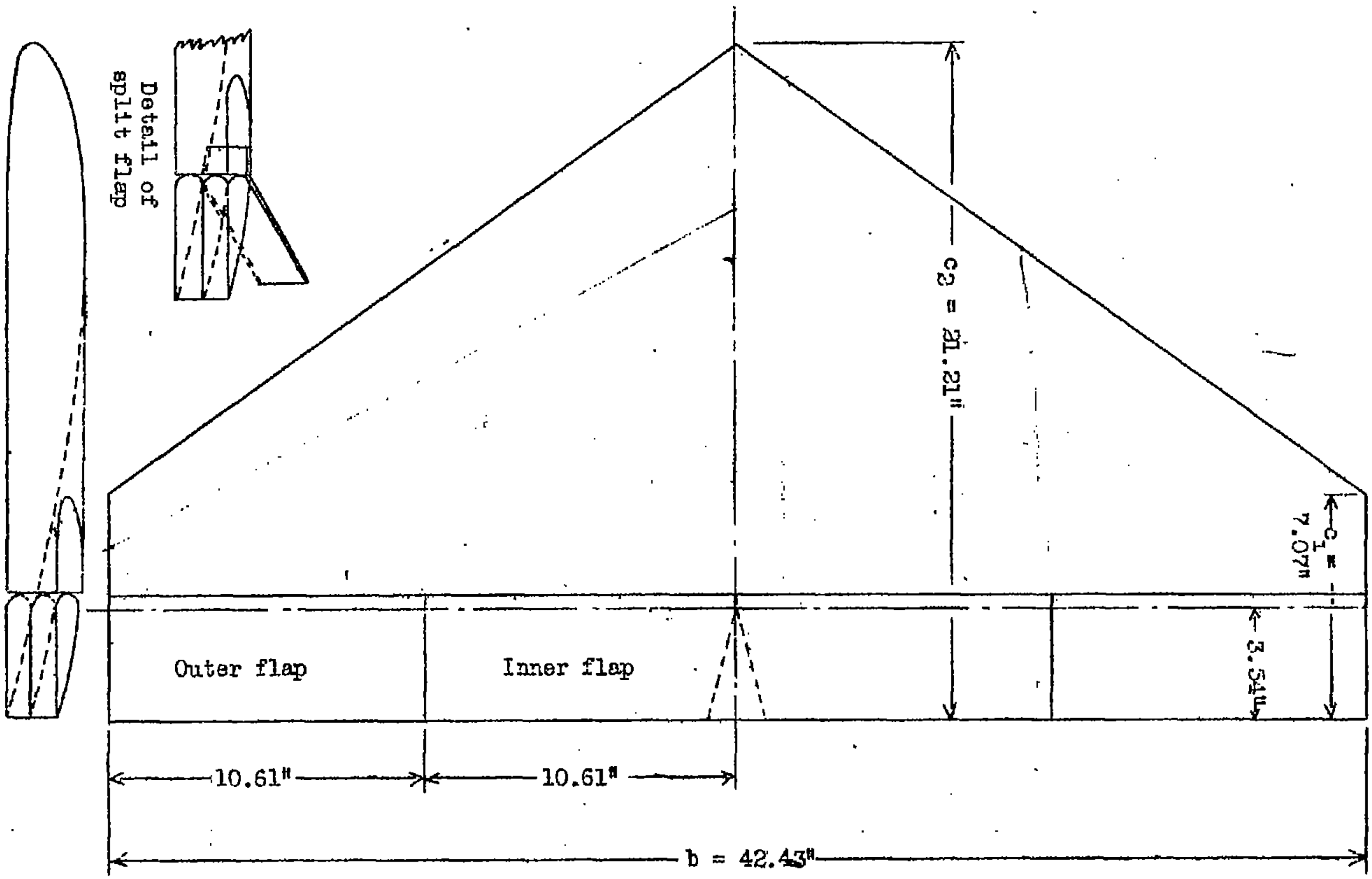

Figure 1.-Sweptback Clark Y airfoil model.

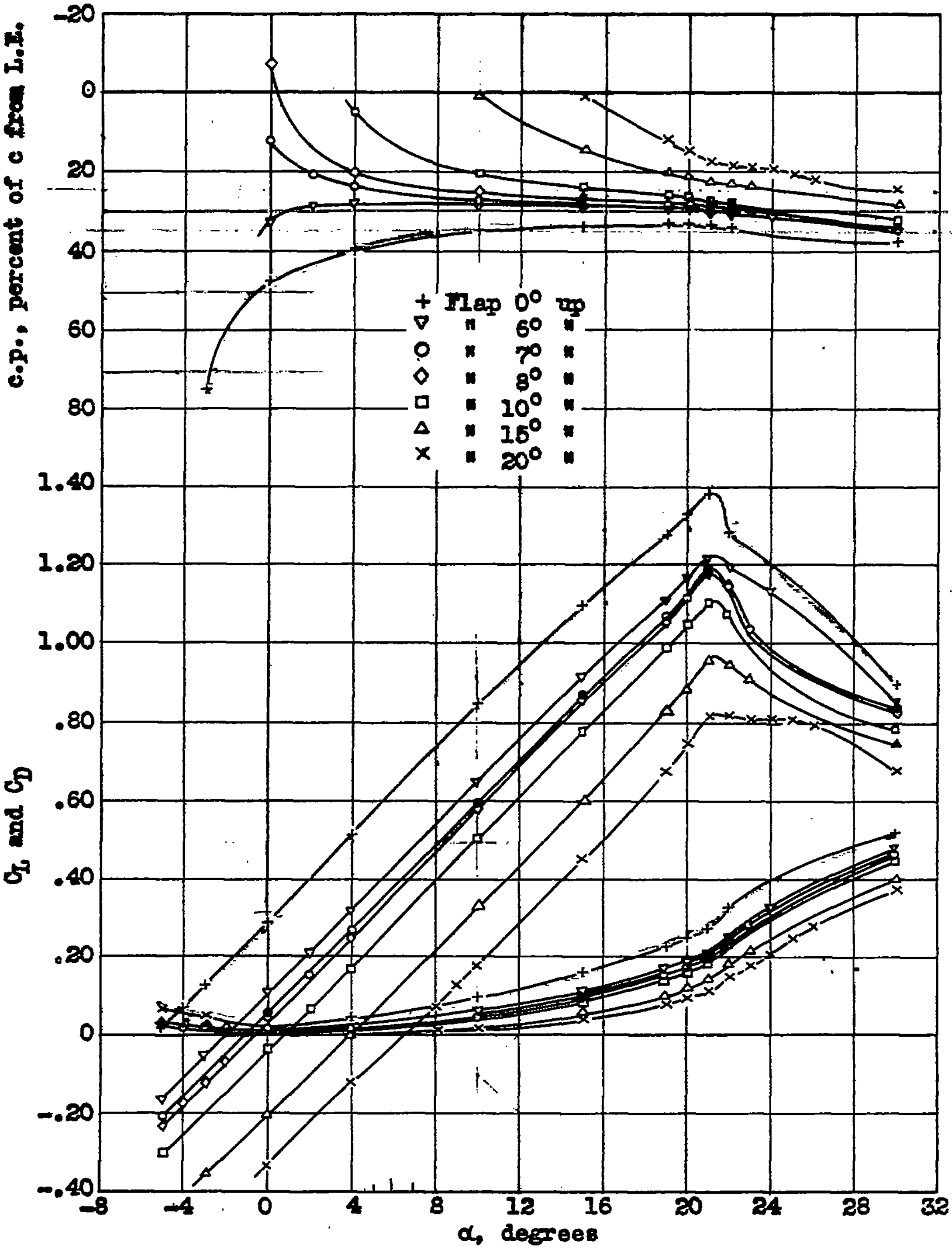

Figure 2.-C_L, C_D, and c.p. with full span plain flap set at various angles.

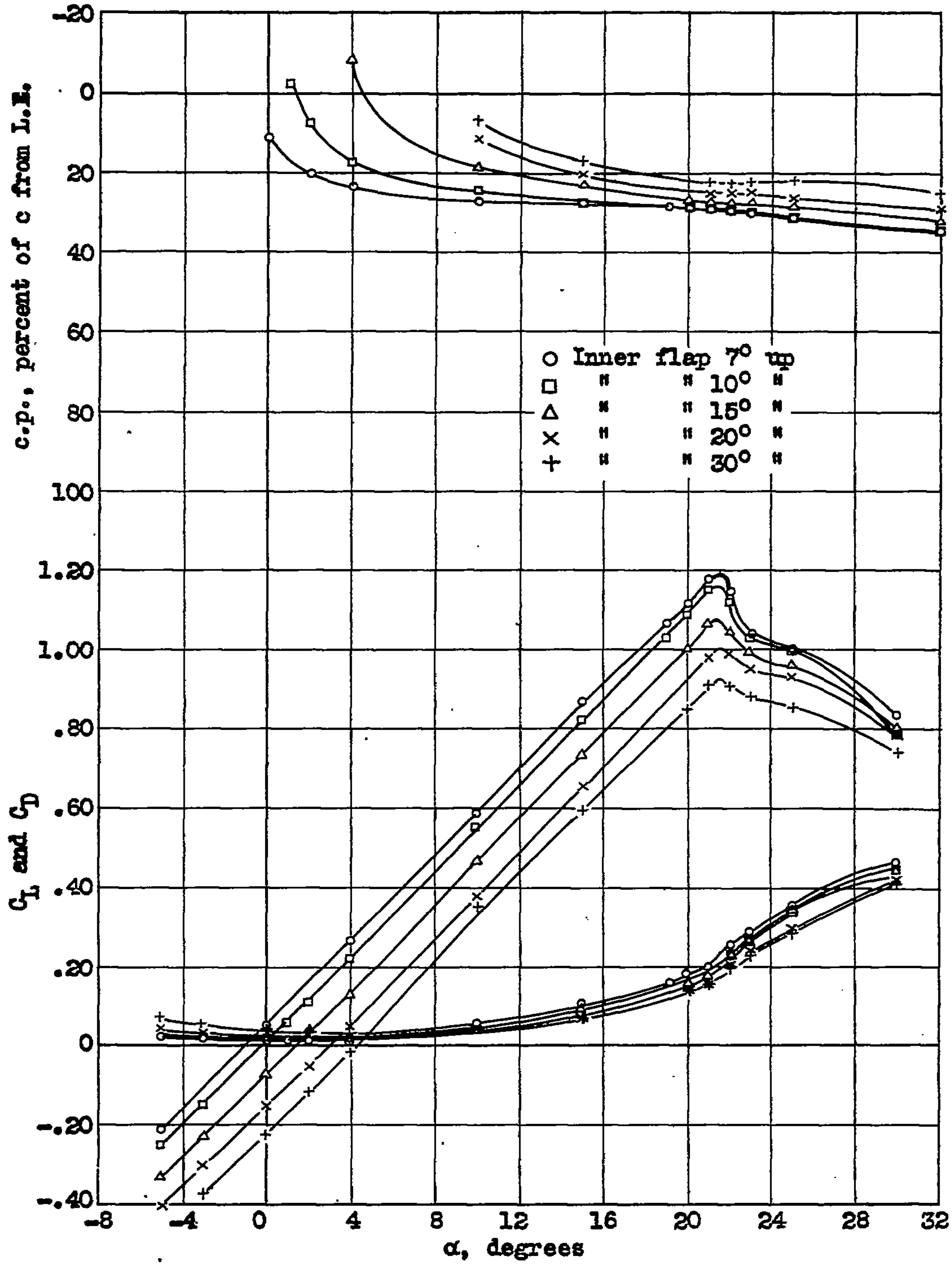

Figure 3.-C_L, C_D and c.p. with full span plain flap divided into four parts of equal span. Outer pair set 7° up, center pair at various angles.

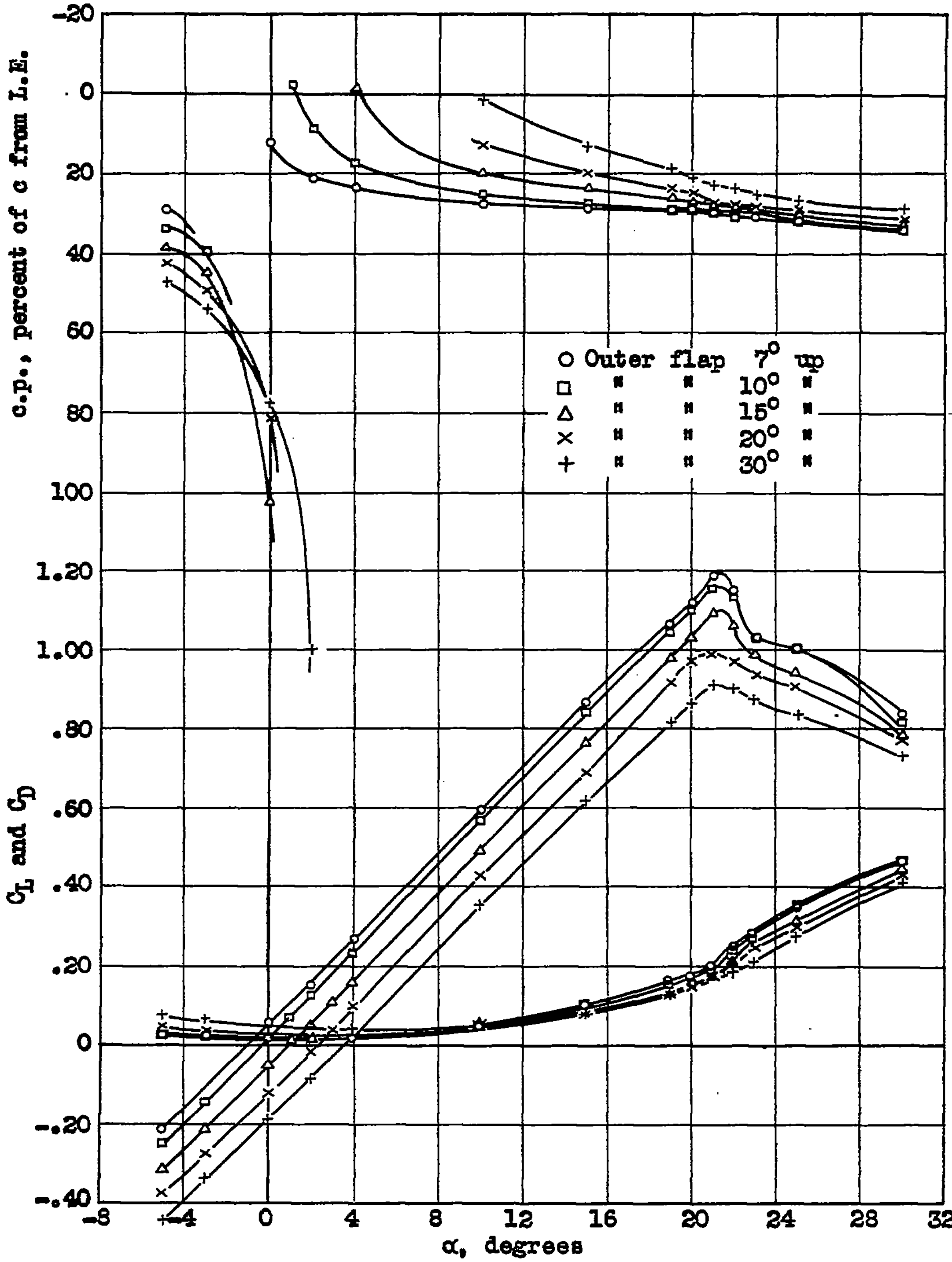

Figure 4.-C_L, C_D and c.p. with full span plain flap divided into four parts of equal span. Center pair set 7° up, outer pair at various angles.

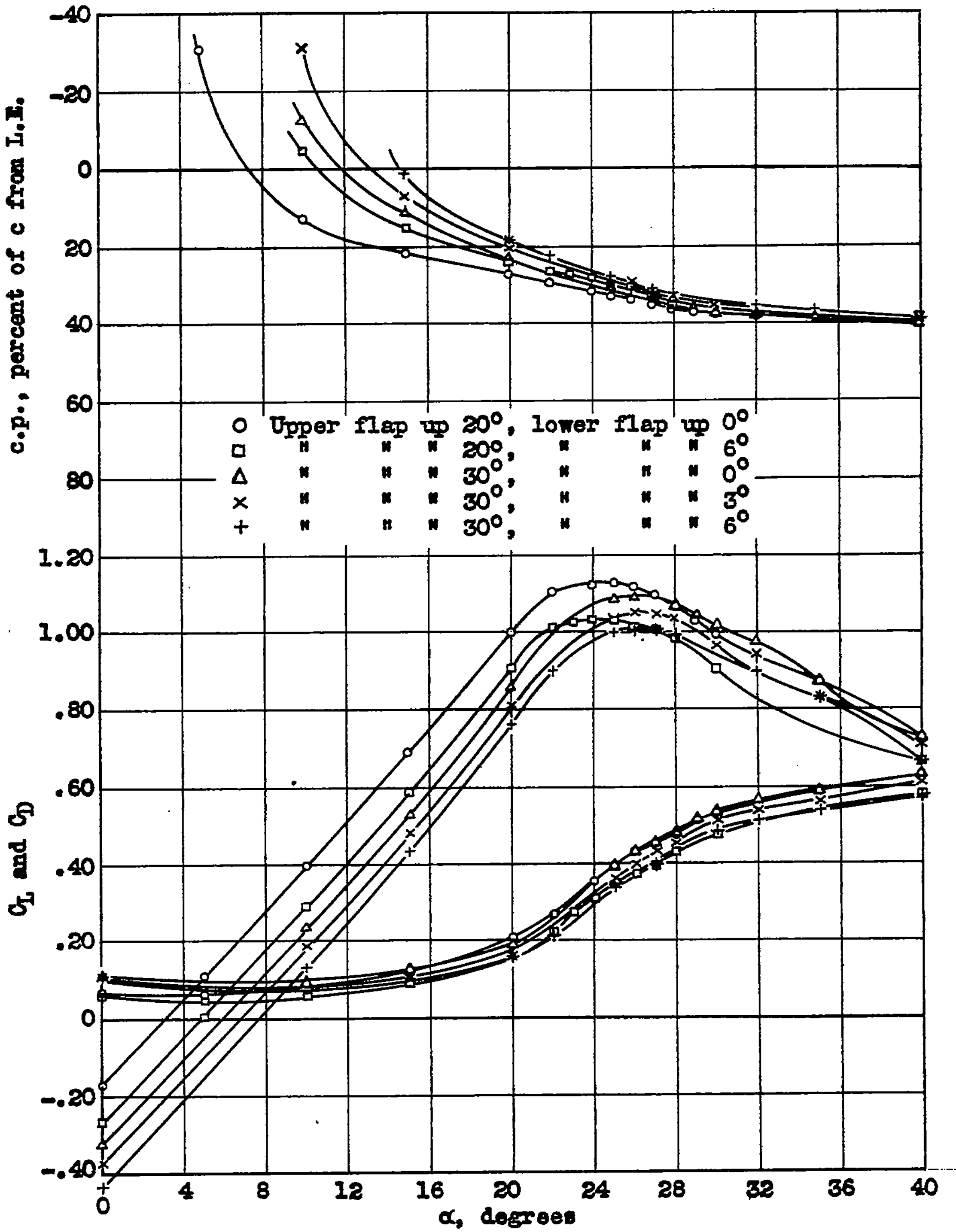

Figure 5.-C_L, C_D and c.p. with full span split flap set at various angles.

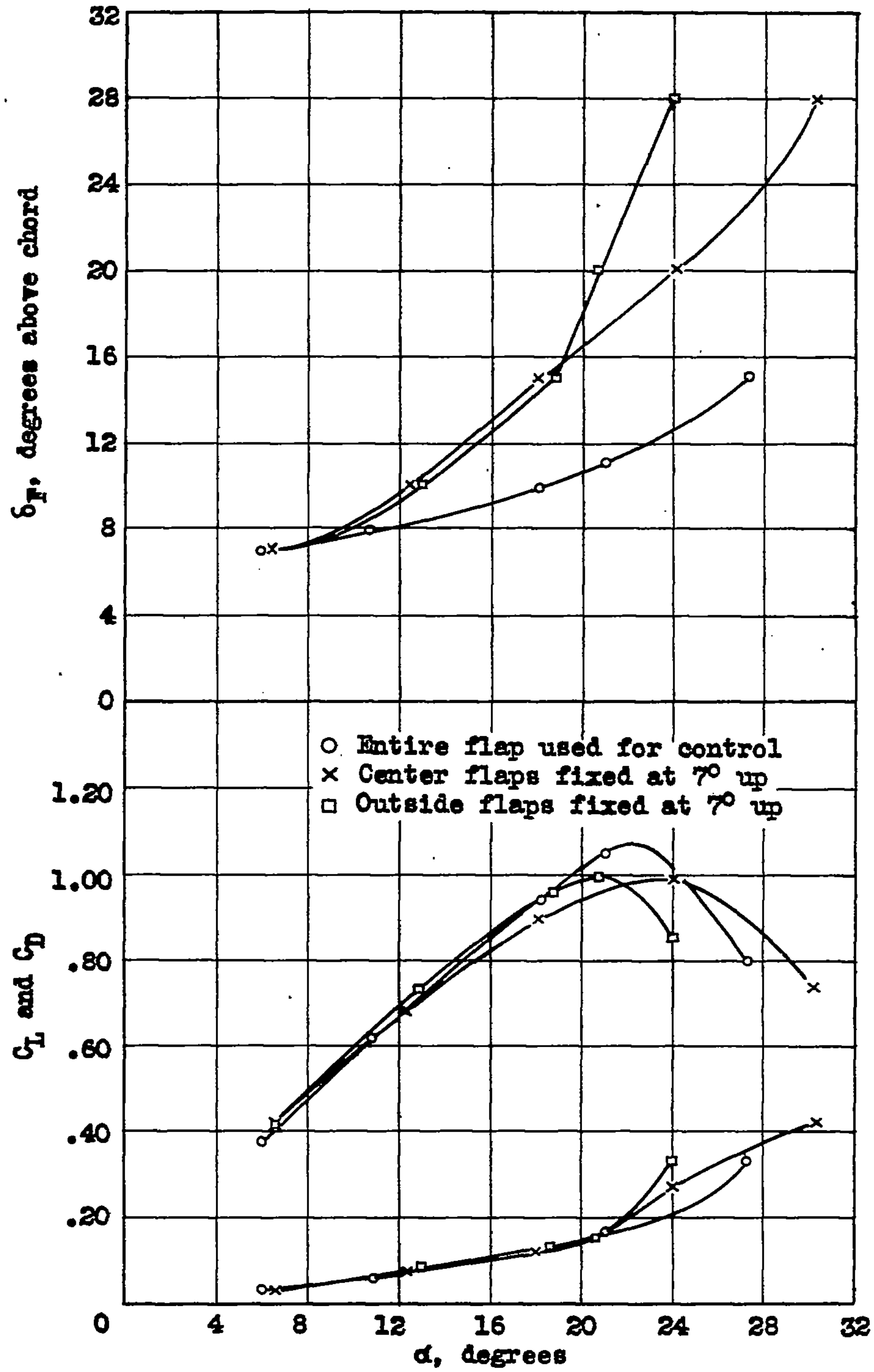

Figure 6.-C_L, C_D and flap angle δ_F for constant c.p. at 26 percent mean aerodynamic chord.